## WEEKLY EVENING MEETING,

Friday, March 15, 1889.

Sir Frederick Bramwell, Bart. D.C.L. F.R.S. Honorary Secretary and Vice-President, in the Chair.

Sir James N. Douglass, F.R.S. *M.R.I.*

### *Beacon Lights and Fog Signals.*

It is stated by Samuel Smiles, in his 'Lives of Engineers,' that "with Winstanley's structure on the Eddystone in 1696, may be said to have commenced the modern engineering efforts," in directing the great sources of power in nature, for the use and convenience of man; efforts, which, followed up by Rudyerd, Smeaton, and others, have been so successful in converting hidden dangers into sources of safety, and ensuring the beneficent guidance of the mariner in his trackless path.

The famous structure of Smeaton, which had withstood the storms of more than half a century with incalculable advantage to mankind, became in course of time a matter of anxiety and watchful care to the Corporation of Trinity House, owing to the great tremor of the building with each wave stroke, during heavy westerly storms. The joints of the masonry frequently yielded to the heavy strains, and the sea-water was driven through them to the interior of the building. The upper part of the structure was strengthened with internal iron-work in 1839, and again in 1865. On the last occasion, it was found that the chief mischief was caused by the upward stroke of the heavy seas against the projecting cornice of the lantern gallery, thus lifting this portion of the masonry, together with the lantern above it. Unfortunately, the portion of the gneis rock on which the lighthouse was founded, had become seriously shaken by the heavy sea strokes on the tower, and the rock had thus been seriously undermined at its base. The waves rose during storms considerably above the summit of the lantern, thus frequently eclipsing the light, and altering its distinctive character from a fixed light to an occulting. This matter of distinctive character in a beacon light, was one of little importance at the date of the erection of Smeaton's lighthouse, when coal fires were the only illuminating agents along the coasts; but with the rapid development of our commerce, and the great increase in the number of coast lights, it has become an absolute necessity that each light maintain a clearly distinctive character. It was, therefore,

determined by the Trinity House, in 1877, to erect a new lighthouse at a distance of 120 feet from Smeaton's tower, where a safe and permanent foundation was found, but at a much lower level, which necessitated the laying of a large portion of the foundation masonry below low water. The foundation stone of this work was laid on the 19th August, 1879, by H.R.H. The Duke of Edinburgh, Master of the Trinity House; assisted by H.R.H. The Prince of Wales, an honorary Elder Brother of the Corporation.

On the 1st June, 1881, H.R.H. The Master, when passing up Channel in H.M.S. *Lively*, landed at the rock and laid the last stone of the tower; and on the 18th May of the following year H.R.H. lighted the lamps, and formally opened the lighthouse. The edifice was thus completed within four years from its commencement, at a cost of 59,255*l*. The work was executed under the immediate direction of the Trinity House and their engineer, and with a saving of 24,000*l*. on the lowest sum at which it had been found that it could be executed by contract. Every block of granite in the structure, is dovetailed together, both vertically and horizontally, on a system devised by my father, and first adopted at the Hanois rock lighthouse, off the west coast of Guernsey. The illuminating apparatus consists of two superposed oil lamps, each of six concentric wicks; and of two drums of lenses of 920 mm. focal distance, twelve lenses in each drum. The optical apparatus is specially designed on the system of Dr. John Hopkinson, F.R.S. for a double flashing light, and shows two flashes in quick succession, at intervals of half a minute. Attention has of late been directed to the subject of superposed lights in lighthouses, which became a necessity when several small luminaries had to be substituted for the large coal, or wood, fire of our early lighthouses. The credit of first superposing lighthouse luminaries is doubtless due to Smeaton, who lighted his lantern in 1759 with 24 large tallow candles in two tiers. The idea was followed in 1790 with the first revolving light, established at the St. Agnes lighthouse, Scilly Islands, which consisted of 15 oil lamps and reflectors, arranged in three groups, and in three tiers. The number of the lamps and reflectors at this and other first-class lights, was afterwards extended to 30, and in four tiers. In 1859 Mr. J. W. D. Brown, of Lewisham, proposed superposed lenses for signal and lighthouse lanterns, with a separate light for each tier of lenses. In 1872 Mr. John Wigham, of Dublin, proposed superposed lenses for lighthouses, in conjunction with his large gas flames, and the first application of these was made in 1877, at the Galley Head lighthouse, County Cork. In 1876 Messrs. Lepaute and Sons, the eminent lighthouse optical engineers of Paris, made successful experiments with superposed lenses and mineral oil flames, and one of their apparatus was exhibited at the Paris International Exhibition of 1878. The results of these experiments were given by M. Henry Lepaute, in a paper contributed to the Congress at Havre, in 1877, of the French Association for the Advancement of Science. The Eddy-

stone represents the first practical application of superposed lenses of the first order, with oil as the illuminant.

The apparatus at the Eddystone is provided with two six wick burners of the Trinity House improved type, and has a minimum intensity for clear weather of about 38,000 candle units, and a maximum intensity of about 160,000 candle units for atmosphere impaired for the transmission of light. The chandelier light in Smeaton's lantern was unaided by optical apparatus. I have found by experiment that the aggregate intensity of the beam from the 24 candles was 67 candle units nearly. The maximum intensity of the flashes now sent to the mariner is about 2380 times that of the candle beam, while the annual cost for the mineral oil illuminant is about 82 per cent. less. The sound signal for foggy weather consists of two bells of 40 cwt. each, mounted on the lantern gallery, and rung by machinery. If any wind occurs with the fog, the windward bell is sounded. The distinctive character of the signal is two sounds of the bell in quick succession every half minute, thus corresponding with the character of the light signal.

The tendency of the curvilinear outline near the base of Smeaton's and of other similar sea towers that have followed it, to elevate the centre of force of heavy waves on the structure, induced me to adopt a cylindrical base for the new lighthouse, which is found to retard the rise of waves on the structure, while it affords a convenient platform for the light-keepers, and adds very considerably to their opportunities for landing and relief. The Town Council and inhabitants of Plymouth having expressed a desire that Smeaton's lighthouse should be re-erected on Plymouth Hoe, in lieu of the Trinity House sea mark thereat, the Trinity House, who, as custodians of public money, had no funds available for such a purpose, undertook to deliver to the authorities at Plymouth, at actual cost for labour, the lanterns and the four rooms of the tower. These have been re-erected by public subscription, on a foundation of granite, corresponding nearly with the lower portions of Smeaton's tower, and it is to be hoped that it will be preserved by the town of Plymouth as a monument to the genius of Smeaton, and in commemoration of one of the most successful and beneficent works in civil engineering.

It is extremely difficult to estimate with a fair degree of accuracy the maximum force of the waves with which some of the most exposed of these sea structures may occasionally have to contend. The late eminent lighthouse engineer, Mr. Thomas Stevenson, carried out a long series of experiments with a self-registering instrument he devised for determining the force of sea waves on exposed structures. He found at the Skerryvore rock lighthouse the Atlantic waves there gave an average force for five of the summer months, in 1843–4, of 611 lbs. per square foot. The average result for the six winter months of the same year was 2086 lbs. per square foot, or three times as great as in the summer months. The greatest force registered was on the 29th March, 1845, during a westerly gale, when a pressure

of 6083 lbs., or $2\frac{3}{4}$ tons nearly, per square foot was recorded. After Smeaton had carefully considered the great defect of the building of Rudyerd at the Eddystone, viz. want of weight, he reported that, "if the lighthouse was to be so contrived as not to give way to the sea, it must be made so strong as that the sea must be compelled to give way to the building." Smeaton also had regard to durability as an important element in the structure, for he adds, "in contemplating the use and benefit of such a structure as this, my ideas of what its duration and continued existence ought to be, were not confined within the boundary of one age or two, but extended themselves to look towards a possible perpetuity." Thus Smeaton soon arrived at the firm conviction that his lighthouse must be built of granite, and of this material nearly all lighthouses on exposed tidal rocks have since been constructed, while those on submerged sandbanks are open structures of iron, erected on screw piles or iron cylinders. The screw pile was the invention of the late Mr. Alexander Mitchell, of Belfast.

We have here a model of the first lighthouse, erected in 1838 on these screw piles, at the Maplin Sands, on the north side of the estuary of the Thames; under the direction of the late James Walker, F.R.S. then Engineer-in-Chief to the Trinity House. A lighthouse on the principle of minimum surface exposed to the force of the waves, of which we have here a model, was erected on the chief rock of the dangerous group of the Smalls, situated about eighteen-and-a-half miles off Milford Haven, by Mr. John Phillips, a merchant and shipowner of Liverpool.

The work was designed and erected under great difficulties by Mr. Henry Whiteside, a native of Liverpool, and a man of great mechanical skill and undaunted courage. Added to his mechanical ability, Whiteside possessed a great love and knowledge of music, and had, previous to the erection of his lighthouse, excelled in the construction of violins, spinnettes, and upright harpsichords. The lighthouse, commenced in 1772, was intended to be erected on eight cast iron pillars, sunk deep into the rock. This material was, however, soon abandoned for English oak, as being more elastic and trustworthy. The work was completed and lighted in 1776, with eight lamps and glass faceted reflectors, similar to the one before us.

In 1817, sixteen improved lamps and silvered paraboloidal reflectors were substituted for these; and the lighthouse, although sorely tried by winter storms, was (with the aid of yearly repairs and strengthening) enabled to send forth its beneficent beam until the year 1856, when the Trinity House commenced the erection of a lighthouse of granite, as shown by this model. The vibrations of the old wooden structure must have been very considerable with heavy storms, for the lightkeepers occasionally found it sufficient to cause a bucket of water, placed in the living room to spill just half its contents. It was in this lighthouse that the painful circumstance occurred in the year 1802, of the death of one of the lightkeepers.

In those days only two men inhabited the lighthouse at a time; one of them was taken ill, and the means employed by his companion for obtaining relief proved ineffectual. He hoisted a signal of distress, but owing to stormy weather no landing could be effected, and after many days of extreme suffering, the poor fellow, named Thomas Griffiths, breathed his last, when the survivor, Thomas Howell, fully realised the awful responsibilities of his position; decomposition would quickly follow, and the atmosphere of the small apartment would be vitiated. The body could not be committed to the sea, as suspicion of murder would probably follow. Howell was a cooper by trade, and he was thus enabled to make a coffin for his dead companion, out of boards obtained from a partition in the apartment. After very great exertion the body was carried to the outer gallery, and there securely lashed to the railing. For three long weeks it occupied this position before the weather moderated, yet night after night Howell faithfully kept his lights brightly burning. When a landing was at last effected, his attenuated form demonstrated the sufferings, both mental and physical, he had undergone; indeed, several of his friends failed to recognise him on his return to his home. Since this sad occurrence the Trinity House have always maintained three lightkeepers at their isolated rock stations. The present lighthouse was designed by the late Engineer-in-Chief of the Trinity House, Mr. James Walker, F.R.S. and I had the honour of executing the work as resident engineer. The foundation stone was laid on the 26th June, 1857, and the light was exhibited on the 7th August, 1861. The work was completed by the Trinity House, at a cost of 50,125*l.*, being about twenty-four per cent. under the lowest amount at which it had been ascertained that it could have been executed by contract.

Probably the most exposed rock lighthouse is that on the Bishop (the westernmost of the rocks of Scilly), shown on the diagram. Its position is doubtless one of the most important to mariners, warning them as it does of the terrible dangers where, on the 22nd of October, 1707, Sir Cloudesley Shovel, with the *Association*, *Eagle*, and *Romney*, were lost, with about 2000 men. The Bishop is also the guiding light for the entrances to the English and Bristol Channels. The rock, composed of a very hard pink-coloured granite, is about 153 feet long by 52 feet wide at the level of low water of spring tides. It stands in over twenty fathoms water, is steep-to all round, and is exposed to the full fury of the Atlantic. It was at first feared that the width of the rock was not sufficient for the base of a stone tower of adequate dimensions to withstand the heavy wave shocks it would have to resist, and an open structure of wrought and cast iron (shown on the diagram) was determined on. The work was jointly designed by the late Engineer-in-Chief to the Trinity House, and my father, the Superintending Engineer, who afterwards erected the structure, at which I had the honour of acting as Assistant Engineer.

The work was commenced in 1847, and at the end of the working

season of 1850, the lighthouse was so far completed as to be in readiness for receiving the lantern and the illuminating apparatus; and it was left with confidence, to resist the storms of the approaching winter. But during a very violent storm, between 11 p.m. of the 5th and 3 a.m. on the 6th of the following February, the lighthouse was completely destroyed and swept from the rock. On further consideration of the matter, the Trinity House determined, on the recommendation of their engineers, to proceed with a stone structure, and my father was appointed to build the lighthouse, I acting as before as Assistant Engineer. The work was proceeded with in the spring of 1851. In order to obtain the greatest possible diameter of base for the tower that the rock would admit of, it was found necessary to lay a portion of the foundation on the most exposed side of the rock, at the level of one foot below low-water of spring tides; and, although every possible human effort was made by the leader, and his devoted band of workers, the foundations were not completed until the end of the season of 1852. Soon after this, my brother, Mr. William Douglass, now Engineer-in-Chief to the Commissioners of Irish Lights, succeeded me as assistant engineer at the work. The lighthouse was completed in 1858, and its dioptric fixed oil light of the first order was first exhibited on the 1st of September of that year. Soon afterwards, its exposure to heavy seas during storms, was fully realised. On one occasion the Fog Bell was torn from its bracket at the lantern gallery at 100 feet above high water, and the flag staff with a ladder, which were lashed outside the lantern, were washed away. The tremor of the tower on these occasions was such as to throw articles off shelves, and several of the large glass prisms of the Dioptric Apparatus were fractured. After some time it was found that several of the external blocks of granite situated a few feet above high water were fractured by the excessive strains on the building. In 1874 the tower was strengthened from top to bottom by heavy iron ties, bolted to the internal surface of the walls; but, after a violent storm in the winter of 1881, there was evidence of further excessive straining at the face of the lower external blocks of masonry, when the Trinity House, on the advice of their engineer, determined on the re-erection of the lighthouse. This was accomplished, as shown on the diagram, by encasing the existing tower with carefully dovetailed granite masonry, each alternate block of the new granite being dovetailed to the old. The work was one of considerable difficulty, owing to the necessity for maintaining the light throughout the progress; and the risk to the workmen was great, especially at the upper part of the old tower, owing to the narrow ledge on which the work had to be executed. I am, however, thankful to state that the new Lighthouse has been successfully completed by my son, Mr. W. T. Douglass, who was also my assistant engineer at the Eddystone; and with the same complete immunity from loss of life, or limb, to any person employed, as with the two previous structures on this rock. The optical apparatus consists of two superposed tiers of lenses of the type adopted at the Eddystone,

but of larger dimensions, as suggested by the late Mr. Thomas Stevenson, for obtaining greater efficiency with the larger flamed luminaries recently adopted. The apparatus is provided with two Trinity House improved mineral oil burners, and has a minimum intensity for clear weather of about 80,000 candle units, and a maximum intensity for thick weather of about 513,000 candle units. The character of the light is Double Flashing, showing two flashes, each of four seconds duration, in quick succession at periods of one minute. The flashes of this light, and those of a light lately completed at about eight nautical miles from it, on Round Island, are the most intense yet attained with oil flames for beacon lights; and it may be stated that, with no other illuminant at present known to science, could these results be carried out within the space available at the Bishop rock, and under the circumstances attending that work. The fog signal recently adopted at this station, in lieu of the bell, is by the electrical explosion of four-ounce charges of gun-cotton, at intervals of five minutes. The apparatus provided for this form of fog signal is shown on the diagram. It consists of a wrought-iron crane (attached to the lantern) which is raised and lowered by a worm wheel and pinion. When the crane is lowered, its end reaches near the gallery, where the lightkeeper suspends the charge of gun-cotton, with its detonator attached, to the electric cable, which is carried along the crane and through the roof of the lantern to a dynamo electric firing machine. After suspending the charge, the jib of the crane is raised to its upper position, when the charge is fired nearly vertically over the glazing of the lantern, and thus without causing damage to it.

The large and heavy optical apparatus is rotated automatically by compressed air, which is stored in two vertical steel reservoirs, fixed at the centre of the tower. The air is compressed by a small Davey Safety Motor. A winch, worked by the compressed air, is fixed on the lantern gallery for landing the lightkeepers, stores, &c.

The numerous outlying shoals surrounding the shores of this country, particularly off the east coast, were an early cause of anxiety to those responsible for the guidance of mariners. And in addition to buoys as sea marks by day, floating lights, as guides by night, were found to be a necessity. The first light-vessel was moored at the Nore Sand in 1732, and another near the Dudgeon Shoal in 1736. We have here a model of the latter vessel, from which we may judge of the pluck and hardihood of the crews who manned them; especially when we remember that there were no chain cables in those days; the vessel having to be moored with a cable of hemp, which, owing to the constant chafing, occasionally parted during winter storms, when, to save their lives, the crew had to put out another anchor if possible, or set such storm canvas as they could, to keep her off a lee shore, and endeavour to reach a place of safety. The illuminating apparatus of these vessels consisted of a small lantern, and

flat wick oil lamps, fixed at a yard arm, and here appears to have occurred the first application of a distinctive character to beacon lights, for the Dudgeon was fitted with two lights, one being placed at each arm of the yard. The next light-vessel was placed at the Newarp Shoal in 1790, and in 1795 one was placed at the north end of the Goodwin Sands. The two latter vessels were provided with three fixed lights, and the lanterns were larger and surrounded each mast-head, as shown by the model before us. An improvement was also effected in these lights by providing each lamp with a silvered reflector.

In 1807 the late Mr. Robert Stevenson, the engineer of the Bell Rock lighthouse, to whom and his successor is due much valuable engineering and optical work connected with coast lighting, designed a larger lantern to surround the mast, and capable of being lowered to the deck for properly trimming the lamps. Soon after the adoption of the system of catoptric illuminations in lighthouses, it was extended to floating lights; each lamp and reflector was hung in gimballs, to ensure horizontal direction of the beams of light during the pitching and rolling of the vessel. We have here one of these apparatus. The intensity of the beam sent from it was 500 candle units nearly.

On the 1st January, 1837, the Trinity House installed the first revolving floating light, at the Swin Middle, and, later in the same year, another on board the Gull light-vessel. The lamps and reflectors were carried on a roller frame surrounding the mast, and rotated through light shafting, by clockwork placed between decks. There were nine lamps and reflectors arranged in three groups, of three each, and thus the collective intensity of each flash was equal to that of three fixed lights, or 1500 candle units nearly. In 1872 the Trinity House further increased the dimensions of the lanterns and reflectors of their floating lights, the lanterns from six to eight feet in diameter, with cylindrical instead of polygonal glazing, and the reflectors from 12 inches to 21 inches diameter at the aperture. These improvements, together with the adoption of improved burners, have effected a considerable increase in the intensity of these lights; and, during the last two years, a further improvement has been obtained, by the adoption of concentric wick burners with more condensed flames, and of higher illuminating power, by which the intensity of the beam from each reflector has been raised to 5000 candle units; being just ten times the intensity of the smaller apparatus; while, by the adoption of mineral oil in lieu of colza, the annual cost for the illuminant has been reduced 51 per cent.

Dioptric apparatus for light-vessels was proposed by M. Letourneau in 1851, several small fixed light apparatus being intended to be employed in each lantern, and arranged nearly in the same way as the reflectors. This arrangement has been adopted in some instances by Messrs. D. and T. Stevenson, engineers to the Commissioners of Northern Lighthouses, and by the engineers of the

French Lighthouse service; but, for efficiency, and adaptability to meet the rough duty to which floating lights are occasionally subjected, in stormy weather and collisions, this system has been found to be inferior for this service to the catoptric.

An interesting experiment was recently made by the Mersey Docks and Harbour Board with the electric arc light, on board one of their light-vessels at the entrance of the Mersey, but unfortunately it did not prove successful. The present difficulties experienced afloat with this powerful illuminant will doubtless be overcome, and it will be found to be, as in lighthouses, by far the most efficient illuminant for some special stations, where a higher intensity than can be obtained with flame luminaries is demanded. Experiments have been in progress during the past two years at the "sunk" light-vessel, off the coast of Essex, for maintaining electrical telegraphic communication with the shore for reporting wrecks and casualties in the locality. This vessel is connected with the Post Office at Walton-on-Naze, through nine miles of cable. The instruments adopted are the Wheatstone A.B.C. "Morse," and the Gower Bell telephone—the telephone for the first time for this purpose on board a vessel at sea, and its efficiency has been found to be so perfect, that it is preferred by the operators to the telegraphic instruments. Many difficulties have been experienced in maintaining reliable communication during stormy weather, owing to consequent wear and tear of the connections with the vessel, but the system, which was designed and carried out by the Telegraphic Construction and Maintenance Company, is now working satisfactorily. Unfortunately, however, it is found to be too costly for adoption, except in very special cases.

In 1876, Mr. Julius Pintsch, of Berlin, patented in this country his system of illuminating buoys or other floating bodies by compressed oil gas, and in 1878 one of these buoys was experimentally tried at sea with success by the Trinity House. The system is similar to that previously adopted by Mr. Pintsch with great success in the lighting of railway carriages, but with the addition for buoys of a specially constructed lantern, containing a small cylindrical lens for a fixed light. Through the kindness of the Pintsch's Lighting Company we have here one of these apparatus, producing an intensity in the beam of about twenty candle units. With the charge of gas contained in the buoy the light is shown continuously, night and day, from two to four months, according to the dimensions of the buoy, without re-filling or requiring any other attention, except occasional cleaning of the lens and the glazing of the lantern. In 1883, Mr. William B. Rickman patented a very ingenious addition to this apparatus for producing occulting or flashing light. The apparatus is automatically worked by the issuing compressed gas on its way from the buoy to the burner. After passing the regulator, where the pressure of the gas is reduced for burning, it enters a cylindrical chamber, covered with a diaphragm of very flexible specially prepared leather; this diaphragm, on being slightly raised by the inflowing

gas, communicates motion to a lever, which, assisted by a spiral spring, closes the inlet pipe, and opens at the same time the passage to the burner. As the gas passes on and is consumed at the burner the diaphragm, by its own weight, assisted by the springs, sinks, and, touching the lever, closes the outlet aperture to the burner, and, at the same moment, opens the inlet of the gas from the buoy for another charge. Thus the light is extinguished while the gas is entering the chamber and until the latter is re-filled, when the passage from the buoy is again closed by the rising of the diaphragm. A small pilot jet is constantly burning to ensure the re-ignition of the gas when re-admitted to the burner. It is evident that several characteristic distinctions of light may be obtained by modifications of this ingenious apparatus. About 150 buoys lighted on the Pintsch system are already rendering valuable service to mariners in various parts of the world. For the more important stations at sea, where light-vessels are now employed, the system is considered to be yet wanting in that trustworthiness which should be the leading characteristic of all coast lighting. Very important experiments have lately been made by the Lighthouse Board of the United States, at their general depôt at Tompkinsville, New York, with buoys lighted electrically by glow lamps, operated through submarine conductors from the shore. These experiments have proved so successful that an installation for marking the Gedney's Channel, entrance of Lower Bay, New York Harbour, with six buoys and 100 candle glow lamps, was lighted on the 7th of November last. Gas buoys were considered inapplicable for this special case, owing to their form and size rendering them liable to break adrift, particularly when struck by floating ice or passing vessels. The buoy adopted for the service consists of a spar 46 feet long, having its lower end shackled direct to a heavy iron sinker, resting on the bottom. At the upper end the buoy is fitted with an iron cage, enclosing a heavy glass jar, in which is placed the glow lamp of 100 candle units intensity. The cable is secured by wire staples, in a deep groove cut in the buoy, and covered by a strip of wood. For a distance of several feet at the lower end of the buoy the cable is closely served with iron wire, over which is wound spun yarn, to prevent injury from chafing on the shackle and sinker. The central station on shore, with steam engines and dynamos in duplicate, is on Sandy Hook, at a distance from the extreme buoys of about three nautical miles. The installation is reported to be working continuously and successfully. For auxiliary or port lights on shore, where no collisions can occur, the Pintsch gas system is found to be very perfect. At Broadness, on the Thames, near Gravesend, the Trinity House erected, in 1855, an automatic lighthouse illuminated on Pintsch's system, as shown by the diagram. This small lighthouse shows a single flashing light, at periods of ten seconds, the flashes having an intensity of 500 candle units. The flashes and eclipses are produced with perfect regularity by special clockwork, which also turns on the gas supply to the burner at

sunset and off again at sunrise. It is also arranged for periodic adjustment, for the lengthening and shortening of the nights throughout the year. This automatic light is in the charge of a boatman, who visits it once a week, when he cleans and adjusts the apparatus, and cleans the glazing of the lantern. An automatic lighthouse similar to that at Broadness has been lately installed at Sunderland by the River Wear Commissioners, on a pier which is inaccessible in stormy weather. In 1881–82 several beacons automatically lighted by petroleum spirit, on the system of Herr Lindberg and Herr Lyth, of Stockholm, were established by the Swedish Lighthouse authorities, and are reported to be working efficiently. In 1885, a beacon or automatic lighthouse on this system was installed by the Trinity House on the Thames, near Gravesend, and has been found to work efficiently. The light is occulting at periods of about two seconds; the occultations are produced by an opaque screen rotated around the light, by the ascending currents of heated air from the lamp acting on a horizontal fan. As there is no governor to the apparatus the periods of the occultations are subject to slight errors compared with those of the gas light controlled by clockwork. In 1844 an iron beacon, lighted by a glow lamp and the current from a secondary battery, was erected on a tidal rock near Cadiz. Contact is made and broken by a small clock, which runs for 28 days, and causes the light to flash for five seconds at periods of half a minute. The clock is also arranged for eclipsing the light between sunrise and sunset. The apparatus is the invention of Don Isas Lavoden, of Cadiz, to whom I am indebted for kindly showing me the light in action when on a visit to Cadiz in 1885. There is every probability that automatic beacons, lighted either by electricity, gas, or petroleum spirit, will, in consequence of their economy in maintenance, be extensively adopted in the future.

Coal and wood fires, the flames produced by the combustion of tallow, nearly all the animal, vegetable, and mineral oils, coal and oil gas, and the lime light, have been employed from time to time in lighthouse illumination, and last but not least, the electric light. None of these illuminants have received such universal application in all positions both ashore and afloat as mineral oil at the present moment, and justly so, when we consider its efficiency and economy for the purpose. So recently as 1822, the last beacon coal fire in this country was replaced by a catoptric oil light, at Saint Bees lighthouse, on the coast of Cumberland. We have here diagrams of two of these coal fire beacons, one of them designed and erected by Smeaton in 1767 on his lighthouse at the Spurn Point, on the east side of the entrance to the Humber. So late as 1845 sperm oil was entirely used in the lighthouses and light-vessels of the Trinity House; but, shortly afterwards, colza was adopted with the same efficiency, and with a saving in annual cost of about 44 per cent. In 1861, experiments were made by the Trinity House for determining the relative efficiency and economy of colza and mineral oil for lighthouse illumi-

nation; but owing to the imperfect refinement of the best samples of the latter then procurable in the market, together with its high price, the result of the investigation was not so satisfactory as to justify a change from colza. In 1869 the price of mineral oil of good illuminating quality and safe flashing point, was found to be procurable at about half the price of colza, when the Trinity House determined to make a further series of experiments, and by these it was ascertained that, with a few simple modifications of the Argand burners then in use, they were rendered very efficient for the purpose, it was also found that these burners were thus considerably improved for the combustion of colza. A change from colza to mineral oil was then commenced, and mineral oil is now generally adopted in the lighthouses and light-vessels of the Trinity House service, and with even greater economy than was at first anticipated; the price of this illuminant being now rather less than one-third that of colza. The most powerful oil burner then in use was one of four concentric wicks, the joint production of Arago and Fresnel, and adopted by the French lighthouse authorities about the year 1825, in conjunction with the then new dioptric system of optical apparatus of Fresnel. The standard intensity of the combined flames of this burner, one of which we have here, was 260 candle units. A further development was made, during the experiments of the Trinity House in 1871, by increasing the number of wicks from four to six, which more than doubled the intensity of the light, while effecting a condensation of the luminary per unit of focal area, or in other words improved the optical efficiency 70 per cent. We have here also one of these burners. I have since devised an Argand burner for the combustion of all illuminating gases and oils, whereby still further condensation of the flames, together with greater intensity and economy of combustion, is obtained, and the glass chimney is protected from breakage. These improvements are effected by a special arrangement and distribution of the air currents through the rings of flame, and between them and the glass chimney. (See Models.) We are thus enabled on this system to increase the dimensions of lighthouse burners, for gas and oil, for ten or more rings of flame. With ten rings we obtain an aggregate intensity, when burning cannel gas and good mineral oil, of considerably over 2000 candle units, while the improved efficiency of the luminary for optical condensation of the radiant light, per unit of focal area, as compared with the luminary of our Fresnel four-wick oil burner, has been in each case increased 109 per cent. With reference to the perfect combustion of these highly condensed flames I may state that the efficiency for gas is exactly double that of the London standard Argand burner, viz. when consuming gas of the London standard of 16 candles, the light produced is at the rate of 6·4, instead of 3·2, candles per cubic foot. In addition to a single ring gas burner of this type we have two burners of ten rings of flame, and models of their flames, one for gas and the other for mineral oil. These burners are all of the Trinity House new pattern, both

gas and oil, and they are of the same general arrangement for combustion, except that the oil burner is provided with cotton wicks. Both produce flames of nearly the same form, dimensions, intensity, and colour.

The first application of coal gas to lighthouse illumination was made at the Troon lighthouse, Ayrshire, in 1827; and in 1847 it was adopted at the Hartlepool lighthouse, Durham; when for the first time it was employed in combination with dioptric apparatus of the first order of Fresnel. The slow progress made with coal gas in lighthouses, except for harbour lights, where the gas could be obtained in their vicinity, as at Hartlepool, was chiefly due to the great cost incurred in the manufacture of the small quantity required, and at the usual isolated positions occupied by coast lighthouses, involving extra cost both for labour and for the extra transport of the coal. In 1865 the attention of lighthouse authorities was directed to gas as an illuminant for lighthouses by Mr. John R. Wigham, of Dublin, whose system was tried in that year at the Howth Bailey lighthouse, Dublin Bay. The gas burner of Mr. Wigham, one of which we have here, consists of seven concentric rings, of single flat-flame burners, amounting in the aggregate to 108. The burner is used without a glass chimney, and thus there is no appreciable condensation of the group of flames for their employment at the focus of optical apparatus, and the relative aggregate intensity of the seven rings of flat flames per unit of focal area, as compared with the four concentric flames of the old four-wick oil burner of Fresnel, are only $2\frac{1}{2}$ per cent. higher than the latter. The burner has five powers for varying states of the atmosphere. For the minimum intensity 28 jets are employed, and with the whole 108 jets there is a maximum aggregate intensity of the flames, with cannel gas, of about 2500 candle units. Several lighthouses on the coast of Ireland have been illuminated with gas on the system of Mr. Wigham, and two at Haisboro, on the coast of Norfolk. In 1878 Mr. Wigham installed at the Galley Head lighthouse, County Cork, his system of superposed gas flames and group flashing light, which consisted of four of his large gas burners vertically superposed. In conjunction with these were four tiers of first order annular lenses, eight in each tier. By successive lowering and raising of the gas flames at the focus of each tier of lenses, he produced his group flashing distinction. This light shows, at periods of one minute, instead of the usual single flash from each lens, or vertical group of lenses, a group of short flashes, varying in number, between six and seven. The unavoidable uncertainty with this system in the number of flashes contained in each group is unfortunate for the mariner, who, with the continued increase in the number of coast lights, requires the utmost precision in the distinctive character adopted for each.

In 1857 an experimental trial of the first magneto-electric machine of Holmes, for the practical application of the electric light, was made

by the Trinity House at Blackwall, under the direction, and to the great delight, of their scientific adviser, Faraday; and after a series of experiments, the satisfactory report of Faraday encouraged the Trinity House to order a practical trial of a pair of the Holmes machines. The trial was made at the South Foreland high lighthouse, by Faraday and Holmes, on the 8th of December, 1858, when electricity was found to be a formidable rival to oil and gas for lighthouse illumination, and this position it maintains to the present day. The trials of this arc light were made at the focus of the first order dioptric apparatus for oil light, which was very imperfect for the purpose, but they were sufficiently encouraging to lead the Trinity House, under the advice of Faraday, to proceed further with the electric light for lighthouses. Faraday thus wrote in his report to the Trinity House: "I beg to state that, in my opinion, Professor Holmes has practically established the fitness and sufficiency of the magneto-electric light for lighthouse purposes, so far as its nature and management are concerned. The light produced is powerful beyond any other that I have yet seen so applied, and in principle may be accumulated to any degree; its regularity in the lantern is great, its management easy, and its care there may be confided to attentive keepers of the ordinary intellect and knowledge." These truly prophetic words of Faraday have been entirely realised; electricity still stands foremost in the illumination of our coasts, and appears destined to be one of the greatest blessings ever conferred on humanity, and more especially on "those who go down to the sea in ships." On the 1st of February, 1862, Holmes's machines and apparatus for the electric light were installed at Dungeness lighthouse, and in 1863 the French lighthouse authorities followed, by an installation of the Alliance Company's magneto-electric machines and apparatus for fixed lights, at each of the two lighthouses at Cape La Hêve. We have here the first dioptric apparatus designed and manufactured by Messrs. Chance Bros. & Co. of Birmingham, for the electric fixed light at Dungeness. We have also one of the Holmes lamps employed there. The lamp used at the previous experiments was devised by M. Duboscq, of Paris. This lamp of Holmes is similar to those of Duboscq and Serrin, excepting that the upper and lower carbons and holders are balanced and regulated through pulleys and small catgut cords, instead of by rack and pinions. The carbons are ¼-inch square, and the mean intensity of the light in the arc was 670 candle units nearly. We have here samples of the carbons employed from time to time in the development of the electric light in lighthouses; we have also a Bergot lamp, fitted with the fluted form of carbons I have recently devised. They are of the dimensions now in use at the Saint Catherine's lighthouse, and are giving a mean intensity in the arc of 40,000 candle units. Cylindrical compressed carbons were soon manufactured for the electric light, and were found to be more homogeneous in quality and the flickering of the light less than with the original square carbons, which were simply sawn from the residual carbon of gas retorts; but

there was still the objectionable crater at the points, whether direct or alternating currents were employed, involving flickering from the incessant shifting of position at the points. A considerable loss of radiant light was also involved, particularly when condensing it optically. The flickering was somewhat reduced by an improvement of Messrs. Siemens, in providing the carbons with a graphite core, but with the increasing powers of currents and in the necessary dimensions of carbons the results were far from satisfactory. With the fluted form of carbon shown on the diagram the formation of the crater is prevented, and the arc is held centrally at the points of the carbons; there is thus, in addition to comparatively steady light, nearly uniform radiation in azimuth, and over a greater vertical angle for optical condensation. It now appears to me, after some practical experience with this form of carbon, that it is impossible to determine a practical limit to the dimensions of carbons that may be efficiently employed. With carbons of the actual size shown on the diagram an intensity of about a million candle units should be produced in the arc, and about 150 millions of candle units in the condensed flashes from the optical apparatus of the dimensions now employed for oil and gas flames in lighthouses. Such an intensity is about 400 times that possible at the focus of such apparatus with a flame luminary. Such results as these were probably in the mind of Faraday when he reported that "in principle this light may be accumulated to any degree." Flashes of the great intensity here referred to could only be employed in atmosphere impaired for the transmission of light. In clear weather they would be found to be far too dazzling to the eyes of the mariner, while an intensity of about 50,000 candle units is found to be sufficient for his guidance, and in thick fog no possible intensity can be of practical value for navigation. There are, however, various gradations of impaired atmosphere, between clear weather and thick fog, in which the highest available intensity is doubtless desirable at many important landfall stations for obtaining the greatest possible range of visibility. On the other hand, at the majority of stations in narrow waters, the maximum intensity now obtained with flame light is found to be more generally efficient for navigation than higher intensities.

In 1881 the question of the relative merits of the three lighthouse illuminants—electricity, gas, and mineral oil—was receiving the attention of the lighthouse authorities of this country, which resulted in the Trinity House accepting the responsibility of carrying out an investigation at the South Foreland, of universal importance to the mariner. In the photometrical and electrical portions of this work the Trinity House were aided by the labours of Professor Harold Dixon, F.R.S. and Professor W. Grylls Adams, F.R.S. which contributed very largely to the success of the investigation. The experiments were carried on during a period of over twelve months, and a vast amount of very valuable evidence was collected from numerous

observers, trained and untrained, scientific and practical. The report of the Committee was presented to both Houses of Parliament, by command of Her Majesty, in 1885. The final conclusions of the Committee are given in the following words: "That for the ordinary necessities of lighthouse illumination, mineral oil is the most suitable and economical illuminant, and that for salient headlands, important landfalls, and places where a very powerful light is required, electricity offers the greatest advantages."

I have already referred to the necessity, with the present development of maritime commerce, that every beacon light maintain a clearly distinctive character. When the optically unaided flames of coal fires were the illuminants of our lighthouses, distinctive characters, owing to the small number of lights then employed, were of little importance, and the only distinctions then possible were the costly ones of single, double, or triple lighthouses at one station; but with the enormous increase that has since occurred in the floating commerce of the world, and with the necessary laws now in operation requiring all vessels to carry lights, trustworthy individuality in coast beacon lights has become a positive necessity. Until very recently the distinctive characters consisted of the following: viz.—fixed white, fixed red, revolving white, revolving red, and revolving white and red alternately. The revolving lights showed a flash at periods of 10 seconds, 20 seconds, 30 seconds, one minute, 2 minutes, 3 minutes, and 4 minutes. There were also intermittent or occulting lights, having an eclipse at periods of half-a-minute, one minute, or 2 minutes. It is now generally considered that fixed lights are no longer trustworthy coast signals, owing to their liability to confusion with other lights, both ashore and afloat. It is also considered that in these days of high speed vessels the period of the character of a coast light should not if possible exceed half-a-minute. The revolving or flashing class of lights are probably the most valuable, on account of their superior intensity, as compared with the fixed or occulting class, the light during the intervals of eclipse being condensed into each succeeding flash by the revolving lenses or reflectors, and thus, with the same expenditure of the illuminant, an intensity is obtained in the flashes of five to eight times that of the fixed or occulting class. Where local dangers are required to be guarded by coloured sectors of danger light with well-defined limits, this can only be accomplished with the fixed or occulting class of lights. We will illustrate this with the model before us. We will also show the clear difference of character, not generally realised, between flashing and occulting lights. A system of occulting lights for lighthouses was proposed by the late Charles Babbage, F.R.S. in 1857; but as it excluded the flashing or most powerful of the existing lights, it did not receive much favour from lighthouse authorities. And in 1872, 'Distinctive Characters for Coast Lights,' was the subject of a paper by Sir William Thomson, F.R.S. at the Brighton Meeting

of the British Association for the Advancement of Science, when he directed attention to the extreme importance of ready identification of lights at sea, and proposed the use of quick-flashing lights, their flashes being of longer or shorter duration; the short and long flashes representing the dot and dash of the Morse alphabet as used in telegraphy. It was found, however, that the number of symbols in one alphabetical code would not be sufficient, on a thickly lighted coast, to ensure individuality, and render each distinction perfectly trustworthy. Further, that very rapid repetition of each symbol is not required by the mariner, and would involve loss of accumulative power in the flashes, besides incurring unnecessary wear and tear in rotating heavy optical apparatus. Yet much is to be done in the direction of simple distinction. At the Montreal Meeting of the British Association, in 1884, I submitted a paper on 'Improvements in Coast Signals,' in which were suggested two alphabetical codes of flashing lights, and one of occulting, all having the same period of the symbol, viz. half-a-minute. In one of the codes of flashing lights long and short flashes were proposed, as previously by Sir William Thomson, and, in the other, there were proposed white and red flashes. In the occulting series, long and short eclipses were proposed to be substituted for the long and short or white and red flashes of the flashing codes. The system has the advantage of application to all existing lighthouse apparatus, and many lights have been altered to selected symbols of each of these series.

Little was ever accomplished in the way of warning or guidance to the mariner during fog, until about the middle of this century. Previously, a few bells had been established at lighthouses in this country and abroad, and gongs of Chinese manufacture had been in general use on board our light-vessels, but both instruments are now acknowledged to be wanting in the efficiency now demanded in fog, to meet the requirements of navigation. The first important improvement in fog signals, for the service of mariners, was made by the late Mr. Daboll in 1851, who submitted to the United States Lighthouse Board, in that year, a powerful trumpet, sounded by air, compressed by horse-power. The apparatus was installed at Beaver Tail Point, Rhode Island, and the favourable results obtained with it stimulated Mr. Daboll, under the encouragement of the United States Lighthouse Authorities, to the further development of the apparatus; and ultimately, he employed Ericsson's Caloric Engine, as the motive power, with automatic gearing for regulating the blasts. In 1854, some experiments on different means of producing sounds for coast signals were made by the engineers of the French Lighthouse Department, and in 1861–2, MM. Le Gros and Saint Ange Allard, of the Corps des Ponts et Chaussées, conducted a series of experiments upon the sound of bells, and the various methods of striking them. In 1862, Mr. Daboll submitted his improved fog trumpet apparatus of about three horse-power in the blasts, to the Trinity House, who, under the

advice of Faraday, made experimental trials with it in London, and afterwards gave it a practical trial at the Dungeness lighthouse, where experiments were made with it against bells, guns, and a reed fog horn of Professor Holmes, whose services have been already referred to in connection with the first practical application of the electric light. This fog horn of Holmes was sounded by steam, direct from one of the boilers employed at the station for his electric light. The results of these experiments were in favour of Daboll's trumpet, and in 1869, one of these instruments was installed on board the Newarp light-vessel. In the same year, Holmes, having effected further improvements with his steam horn, his apparatus was fitted on board two light-vessels and sent out to the coast of China, where they were found to give great satisfaction, as compared with gong signals. In 1863 a committee of the British Association for the Advancement of Science memorialised the President of the Board of Trade, with the view of inducing him to institute a series of experiments upon fog signals. The memorial, after briefly setting forth a statement of the nature and importance of the subject, described what was then known respecting it, and several suggestions were made relative to the nature of the experiments recommended. The proposal does not appear to have been favourably entertained by the authorities to whom it was referred, and the experiments were not carried out. In 1864 a series of experiments was undertaken by a commission appointed by the Lighthouse Board of the United States to determine the relative powers of various fog signals which were submitted to the notice of the Board. In 1872, a committee of the Trinity House, with the object of ascertaining the actual efficiency of various fog signals then in operation on the North American Continent, visited the United States and Canada, where they found in service Daboll's trumpets, steam whistles, and siren apparatus, devised by Mr. Felix Brown, of Progress Works, New York, sounded by steam and compressed air. From the report of the Trinity House Committee, it does not appear that they were greatly impressed with this instrument, but probably they had not an opportunity of testing its real merits, as compared with other signals. The late Professor Henry, of the United States Lighthouse Board, entertained a very high opinion of the siren, and on his advice, and the urgent recommendation of Professor Tyndall, one of these instruments was sent to England and included in the fog signal experiments at the South Foreland in 1873–4. This investigation was carried out by the Trinity House, with the view of obtaining definite knowledge as to the relative merits of various sound-producing instruments then in use, and also of ascertaining how the propagation of sound is affected by meteorological phenomena. Professor Tyndall, as scientific adviser of the Trinity House, conducted the investigation, aided by a committee of the Trinity House and their engineer. These experiments were extended over a lengthened period, in all conditions of weather, and the well-

known scientific and practical results obtained, together with the ascertained relative merits of sound-producing instruments for the service of the mariner, have proved to be of the highest scientific interest and practical importance. The investigation at the South Foreland was followed up by the Trinity House with further explosive fog signal experiments, in which they were assisted by the authorities at Woolwich Arsenal, with guns of various forms, weight of charges, and descriptions of gunpowder. The powders tested were —(1) fine grain, (2) larger grain, (3) rifle large grain, and (4) pebble. The result placed the sound-producing powers of these powders exactly in the order above stated; the fine grain, or most rapidly burning powder, gave indisputably the loudest sound, while the report of the slowly burning pebble powder, was weakest of all. Here, again, the greater value of increased rapidity of combustion in producing sound, was demonstrated. It was found that charges of gun-cotton yielded reports louder at all ranges than equal charges of the best gunpowder; and further experiments proved the explosion of half-a-pound of gun-cotton gave a sound equal in intensity to that produced by three pounds of the best gunpowder. These investigations led the Trinity House to adopt gun-cotton for fog signals at isolated stations on rocks and shoals, as already described, where, from want of space, it had hitherto been possible to apply nothing better than a bell, or gong. Of all the sound signals now employed, for the warning and guidance of mariners during fog, viz. bells, gongs, guns, whistles, reed trumpets, sirens, and sounds produced by the explosion of gun-cotton, the blasts of the siren, and explosions of gun-cotton, have been found to be the most efficient for coast fog signals; therefore these signals have received the greatest care and attention in their development. The siren doubtless ranks first, for stations wherever it can be applied, chiefly on account of its economy in maintenance, and the facility it affords for giving prolonged blasts of any desired intensity or pitch, and thus providing any number of trustworthy distinctive characters that may be required to ensure individuality in the signal. Sirens are now employed at many floating and shore stations of the Trinity House, and one recently installed at Saint Catherine's Lighthouse, Isle of Wight, of the automatic Holmes type, of which we have here a model, absorbs during its blast not less than 600 horse-power. The audibility of the blasts of this instrument may be considered to be trustworthy at a range of two miles under all conditions of foggy atmosphere on the sea surface over which it is intended to be sounded. It is very desirable that for many landport stations a greater trustworthy range be provided for the mariner, but this can only be afforded by such increased power as would be required for a more powerful electric light installation to serve the mariner in other gradations of thick atmosphere. A very important improvement and economy have lately been effected in the sirens of the Trinity House by rendering them always instantaneously available for

sounding at their maximum power. This is accomplished by the storage of a sufficient quantity of compressed air to work the siren during the time required for raising steam and starting the engine. The signal is thus always in readiness for immediate action, day or night, with an expenditure of fuel only incurred during fog, which on the coast of this country does not exceed an average of 440 hours per annum. The experience yet gained with the most powerful fog signals now in use, although these apparatus far exceed in efficiency, for the service of the mariner in fog, any light that science can provide, is not yet so satisfactory as we could desire. The best signal is, as I have already stated, occasionally not heard, under certain atmospheric conditions, beyond two miles; while under other conditions, not apparent to the mariner, the signal is distinctly audible at ten miles: therefore there is much to be desired in the development of the means of propagating sound waves, and in rendering them audible to the mariner. In conclusion, I would venture to state that, with the best light and sound signals that can be provided, there are conditions of the atmosphere in which the mariner will earnestly look and listen in vain for the desired light or sound signal, and he must still, under such circumstances, exercise caution in availing himself of their guidance, and never neglect the assistance always at hand of his old trusty friend the lead.

[J. N. D.]

---

## WEEKLY EVENING MEETING,

Friday, March 22, 1889.

Colonel J. A. Grant, C.B. C.S.I. F.R.S. Vice-President, in the Chair.

Eadweard Muybridge, Esq.

*The Science of Animal Locomotion in its Relation to design in Art.*

(Illustrated by the Zoopraxiscope.)

[No Abstract.]

---

## WEEKLY EVENING MEETING,

Friday, March 29, 1889.

William Crookes, Esq. F.R.S. Vice-President, in the Chair.

A. Gordon Salamon, Esq. F.C.S. *M.R.I.*

*Yeast.*

[Abstract deferred.]